# USE OF MODELS TO ESTABLISH SOURCE - RECEPTOR RELATIONSHIPS AND ESTIMATE RELATIVE SOURCE CONTRIBUTIONS OF $NO_x$ TO AIR QUALITY PROBLEMS

by

John H. Seinfeld and Gregory J. McRae
California Institute of Technology
Pasadena, California 91125

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Project Officer
Jerry Romanovsky (MD-59)
Environmental Sciences Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

# INTRODUCTION

A basic objective of the Technical Symposium on the Implications of a Low $NO_x$ Vehicle Emission Standard is to examine the need for and technical feasibility of a low $NO_x$ emission standard for future light-duty motor vehicles. A major component of this assessment is to estimate the changes in air quality that would result from the imposition of a low $NO_x$ vehicle emission standard. Such an assessment requires a method for relating emission to air quality changes, i.e. a so-called air quality model. In this summary, we focus on those air quality models that may be used to estimate the impact of changes in the $NO_x$ emission levels from motor vehicles.

To evaluate the impact of a control measure such as a low $NO_x$ standard for vehicles, it is necessary to have a formal methodology for relating ambient air quality changes to emission changes. A variety of mathematical models are available, each representing the underlying chemical and meteorological phenomena in varying degrees of accuracy and sophistication. In selecting an air quality model for performing such an estimation, the following issues should be considered:

1. Is the methodology a valid representation of the physical processes occurring in the atmosphere?
2. Can the methodology be verified?
3. Are the outputs consistent with requirements of the standards?
4. What are the input data requirements?
5. What resources are required to implement the modeling approach?

Any projection of the impact of a low $NO_x$ vehicle emission standard must consider the influence of other proposed control measures. Depending on the $NO_x$ emission distribution between mobile and stationary sources the standard may have to be evaluated on a city by city basis. A crucial region of concern with respect to a vehicle $NO_x$ standard is the South Coast Air Basin (SCAB) of California. Considering the availability of emission inventories, air quality and meteorological data, the SCAB is an ideal location to test different modeling techniques and at the same time to assess carefully the impact of the proposed standard.

In this summary, we address three issues:

1. What air quality models are available for estimating the effect of a low $NO_x$ vehicle emission standard?
2. What are the relative strengths and weaknesses of the modeling approaches?
3. What are the estimated impacts of selected hydrocarbon and $NO_x$ control strategies, including the low $NO_x$ vehicle emission standard?

## SUMMARY OF AIR QUALITY MODELS APPROPRIATE FOR ASSESSING THE IMPACT OF A LOW $NO_X$ VEHICLE EMISSION STANDARD

The elements of a mathematical model for relating pollutant emissions to air quality are shown in Figure 1. Each of the physical and chemical processes indicated in Figure 1 is represented to a greater or lesser degree by each of the air quality models available. A simplified structure of the components in an emission inventory is shown in Figure 2. By structuring an emission inventory in the manner shown in Figure 2 it is possible to vary the emissions from motor vehicles and, in fact, from particular types of motor vehicles without altering the remainder of the inventory. Such a structuring will be important in studies in which the effect of $NO_x$ emission changes for motor vehicles is assessed.

In this section we will consider two basic types of air quality models. The models can be distinguished as producing either relative or absolute indications of air quality changes. A model that produces a relative measure indicates the relative change in air quality as a result of an emission level change. Such a model is typified by the Empirical Kinetic Modeling Approach (EKMA) developed by the U.S. Environmental Protection Agency. A model that produces absolute predictions computes absolute air quality concentrations given a specific emission inventory and set of meteorological conditions. Relative changes in air quality are then determined from the absolute predicted levels of air quality at the two emission levels.

### THE EMPIRICAL KINETIC MODELING APPROACH

The physico-chemical basis of EKMA is similar to that of a trajectory-type model. A hypothetical column or parcel of air, approximating a well-mixed smog chamber, is permitted to move under the influence of the local meteorological conditions. A schematic representation of the trajectory model is shown in Figure 3. The parcel is advected with a mean wind velocity that does not vary with height, and the vertical component of velocity is neglected. Horizontal movement of air at the boundaries is neglected. The column extends from the earth's surface to the top of the mixed layer. The volume of the column increases as the inversion rises.

The customary EKMA simulation period is nine hours corresponding to the hours between 8 a.m. and 5 p.m. LDT (local daylight saving time). Although the EKMA simulation period begins at 8 a.m., the initial NMHC/$NO_x$ ratio is determined from the average of the 6 to 9 a.m. hydrocarbon and nitrogen oxide concentrations. The initial conditions reflect the effects of concentrations from the previous day and night and emissions prior to 9 a.m. Uniform concentrations of ozone and its precursors are assumed to exist above the mixing layer due to air masses trapped above the mixing height at night. As the inversion layer rises during the day, these pollutants are re-entrained from

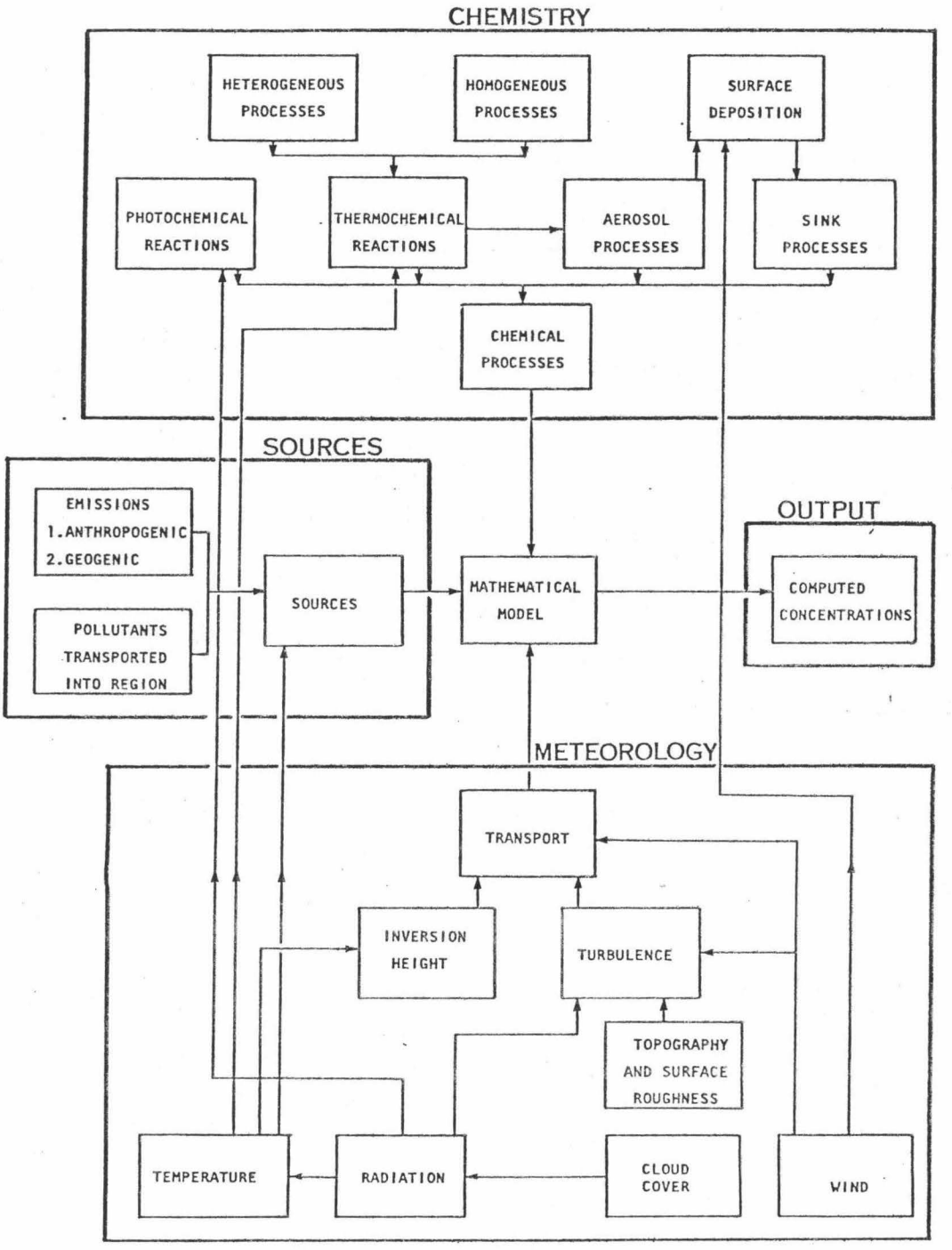



Figure 1. Elements of a mathematical model for relating pollutant emissions to ambient air quality

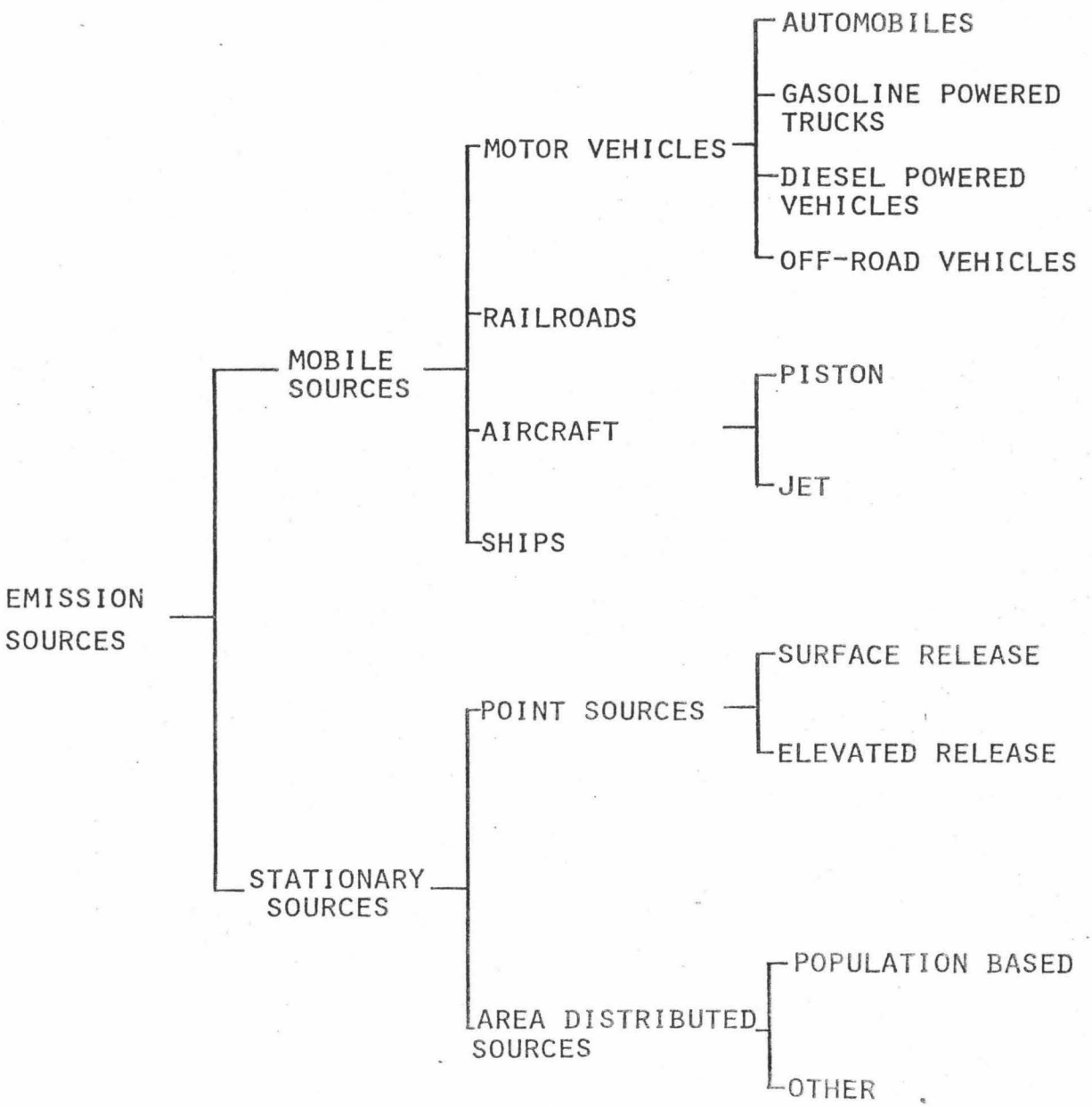



Figure 2. Simplified structure of the components in an emissions inventory

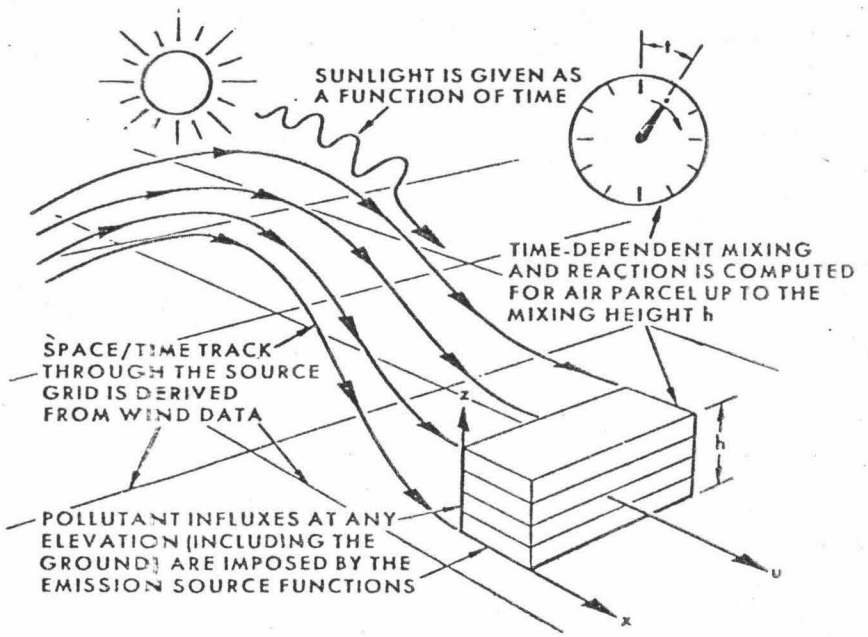



Figure 3. Schematic representation of a trajectory model

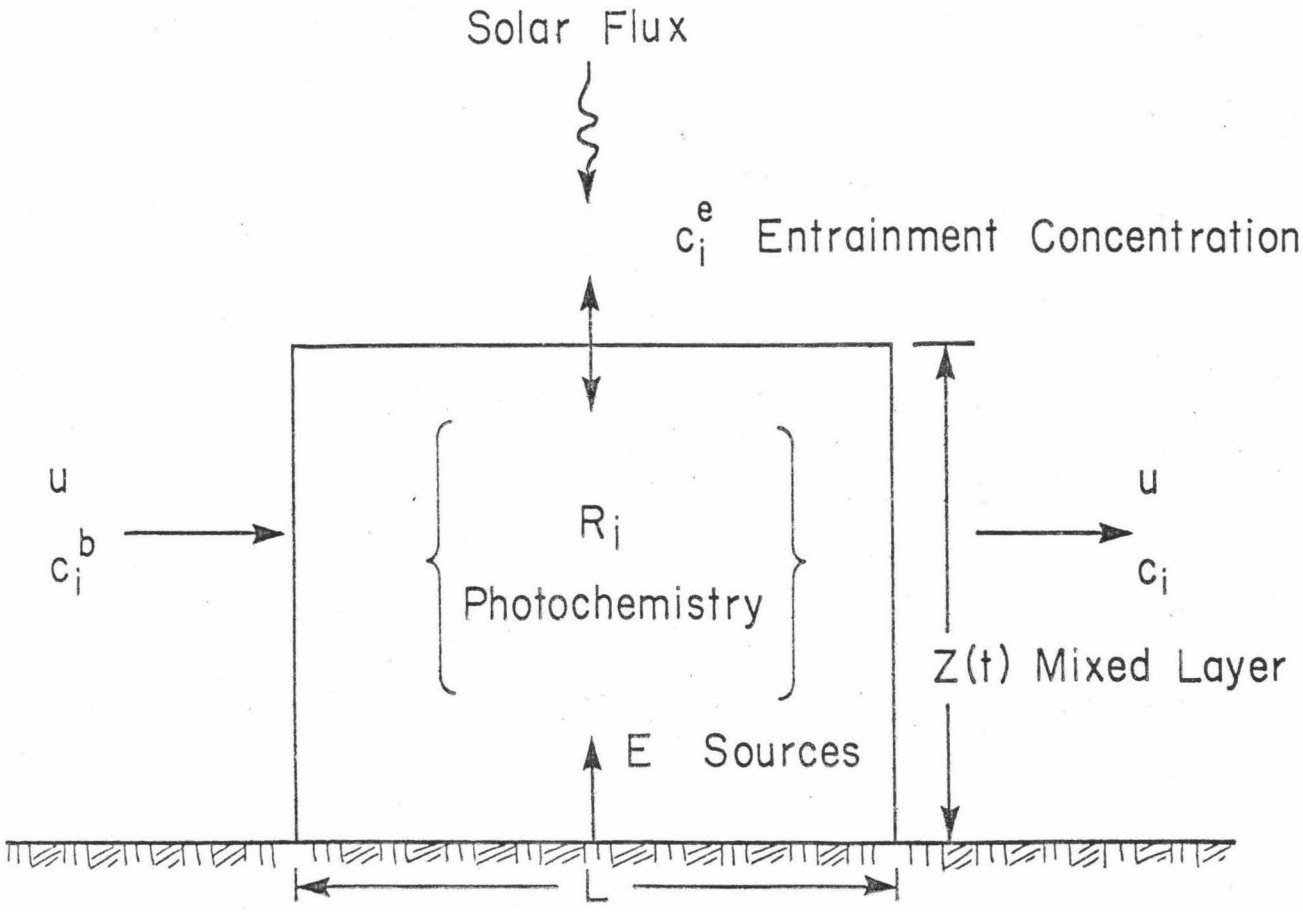
aloft. The parcel also encounters fresh precursor emissions as it moves along its trajectory. Figure 4 provides a schematic represention of the changing column volume and pollutant concentrations along the trajectory.

The rate of change of pollutant concentrations in the parcel is described by a set of coupled, first-order, nonlinear, ordinary differential equations. Each equation represents the conservation of mass for a particular species. The general form of the mass balance is given in Figure 4. The EKMA chemistry is based on a surrogate chemical mechanism involving the series of chemical reactions given by Dodge (1976). The mechanism describes the chemical changes that occur for a mixture of propylene, n-butane, nitric oxide, and nitrogen dioxide. The mechanism was developed using data from smog chamber studies of irradiated auto exhaust and nitrogen oxide mixtures conducted by the Bureau of Mines. In the solution of the governing equations of EKMA, the concentrations are calculated only along the trajectory path, and at any point on the path, only at the time when the column passes that point. Ozone isopleth diagrams are generated by multiple runs in which the initial hydrocarbon and nitrogen oxide concentrations are varied. Each point on the isopleth diagram is the result of a single run for particular precursor concentrations.

The Standard Ozone Isopleth Diagram is shown in Figure 5. In this case, the model uses the fixed assumptions embedded in the computer program. The Standard Isopleth values are used in the EKMA simulations unless the user specifies other values for the variable input data.

The reactive hydrocarbon composition in the Dodge mechanism is represented by a surrogate mixture of propylene, n-butane, and aldehydes. Because of its low reactivity, methane is not considered. Propylene and butane represent the nonmethane hydrocarbons (NMHC). The total carbon atom concentration is the sum of the NMHC concentration and the aldehyde concentration. The Standard Isopleth Diagram uses an initial propylene/butane split of 25 percent propylene and 75 percent n-butane as carbon for the pre-0900 emissions. It is also assumed that 5 percent of the initial carbon atoms are present as aldehydes. The initial aldehyde composition is fixed at 40 percent formaldehyde and 60 percent acetaldehyde as carbon. The composition of the precursors can be altered by changing the initial $NO_2$ fraction of the initial NO concentration, the NMHC composition, or the initial fraction of carbon atoms that is added as aldehydes. $NO_x$ is the sum of the concentrations of nitric oxide (NO) and nitrogen dioxide ($NO_2$). The Standard Isopleth value of the initial $NO_2/NO_x$ ratio for the pre-0900 emissions is 0.25.

The concentrations resulting from the pre-0900 emissions are shown on the NMHC and $NO_x$ axes of the ozone isopleth diagram. The initial concentrations of hydrocarbons and nitrogen oxides include the pre-0900 emissions and background concentrations transported in the surface layer from upwind locations prior to the beginning of the simulation. Emitted species include nitric oxide, nitrogen dioxide, propylene, n-butane, acetaldehyde, and formaldehyde. Background species include propylene, n-butane, nitrogen dioxide, and ozone. The background concentrations of pollutants are assumed to be zero unless otherwise specified. The NMHC background concentrations are




$$\frac{dc_i}{dt} = R_i + \frac{E_i}{Z_i} + \boxed{\frac{u}{L}(c_i^b - c_i)} + \frac{(c_i^e - c_i)}{Z_i}\frac{\partial Z_i}{\partial t}$$

Figure 4. Mass balance equation for the EKMA model

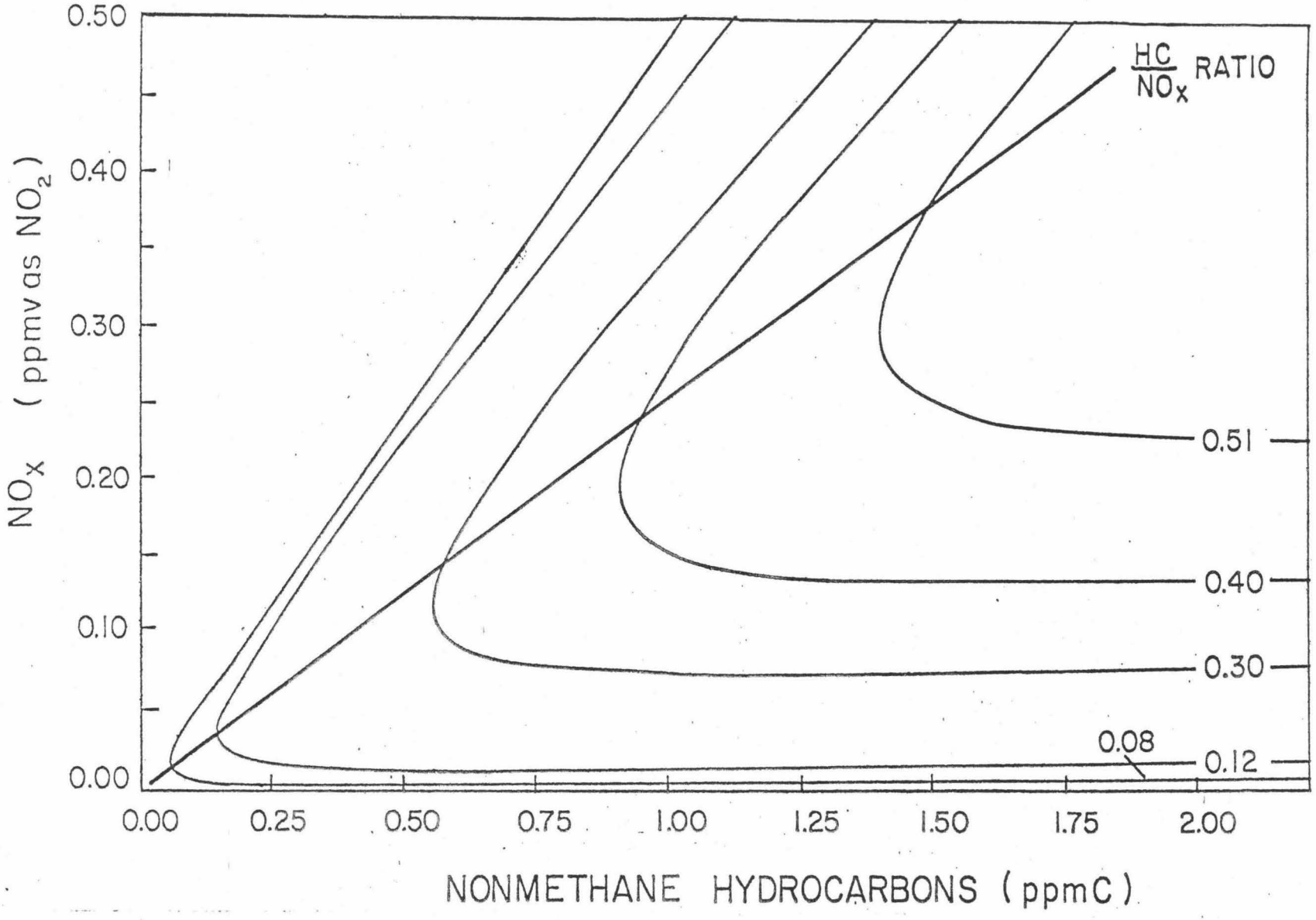



Figure 5. Standard ozone isopleth diagram

assumed to be 10 percent propylene and 90 percent n-butane as ppmC. The $NO_x$ transported within the surface layer is assumed to be 100 percent $NO_2$. In generating an isopleth diagram, the initial NMHC and $NO_x$ concentrations are determined internally by EKMA.

Emissions occurring after the beginning of the simulation can be included by specifying the fractions of the pre-0900 emissions to be added each hour. The post-0900 hydrocarbon emissions are assumed to have the same propylene/n-butane split and aldehyde fraction as the pre-0900 emissions. However, the $NO_x$ split is assumed to be 90 percent NO and 10 percent $NO_2$ and cannot be altered. The fractions of initial NMHC and $NO_x$ to be added each hour are modified to account for the volume change associated with dilution. The Standard Isopleth conditions assume that the post-0900 emissions are negligible.

Dilution in EKMA results from the rise of the mixed layer. The height of the column is assumed to change exponentially with time during a specified period and remain constant at other times. An exponential variation is equivalent to a constant percentage dilution per unit time. No dilution is assumed to occur before and after the inversion rise period. Information is needed regarding the minimum mixing height, the maximum mixing height, and the time over which the inversion rise takes place; the Standard Isopleth values of 510 meters, 630 meters, and 7 hours beginning at 0800, respectively, correspond to a dilution rate of 3 percent per hour.

EKMA will consider the transport of pollutants within air masses trapped above the inversion height from the previous night. As the mixing height rises during the day, the pollutants are entrained into the mixing layer from aloft. Ozone, nitrogen dioxide, propylene, and n-butane are the only species subject to entrainment. The NMHC concentration is fixed at 10 percent propylene and 90 percent n-butane, as carbon. The concentrations aloft are assumed to be constant with time and to extend uniformly to at least the height of the afternoon mixed layer. Entrained pollutants are assumed to be instantaneously mixed with the enlarged parcel of air.

EKMA can be used to predict the percent reductions in NMHC and $NO_x$ needed to achieve a desired ozone concentration based on a measured ozone value. Only the NMHC/$NO_x$ ratio and an observed maximum one-hour average ozone concentration are needed to use the methodology. The NMHC/$NO_x$ ratio is determined from the 6 to 9 a.m. average NMHC and $NO_x$ concentrations. The design ozone value is the maximum one-hour average concentration observed by all monitoring stations within the area 15 to 30 km downwind of the central business district during the base year.

Figure 6 illustrates the steps involved in the use of EKMA to estimate the reductions in precursor emissions necessary to meet the National Ambient Air Quality Standards in some future year. If information is available regarding the city-specific variable input for the urban area of interest, isopleth diagrams should be based on this information. In the case where the future year conditions differ from those of the base year, isopleth diagrams should be generated for each year. The Standard Isopleth Diagram may be used in the absence of city-specific data.

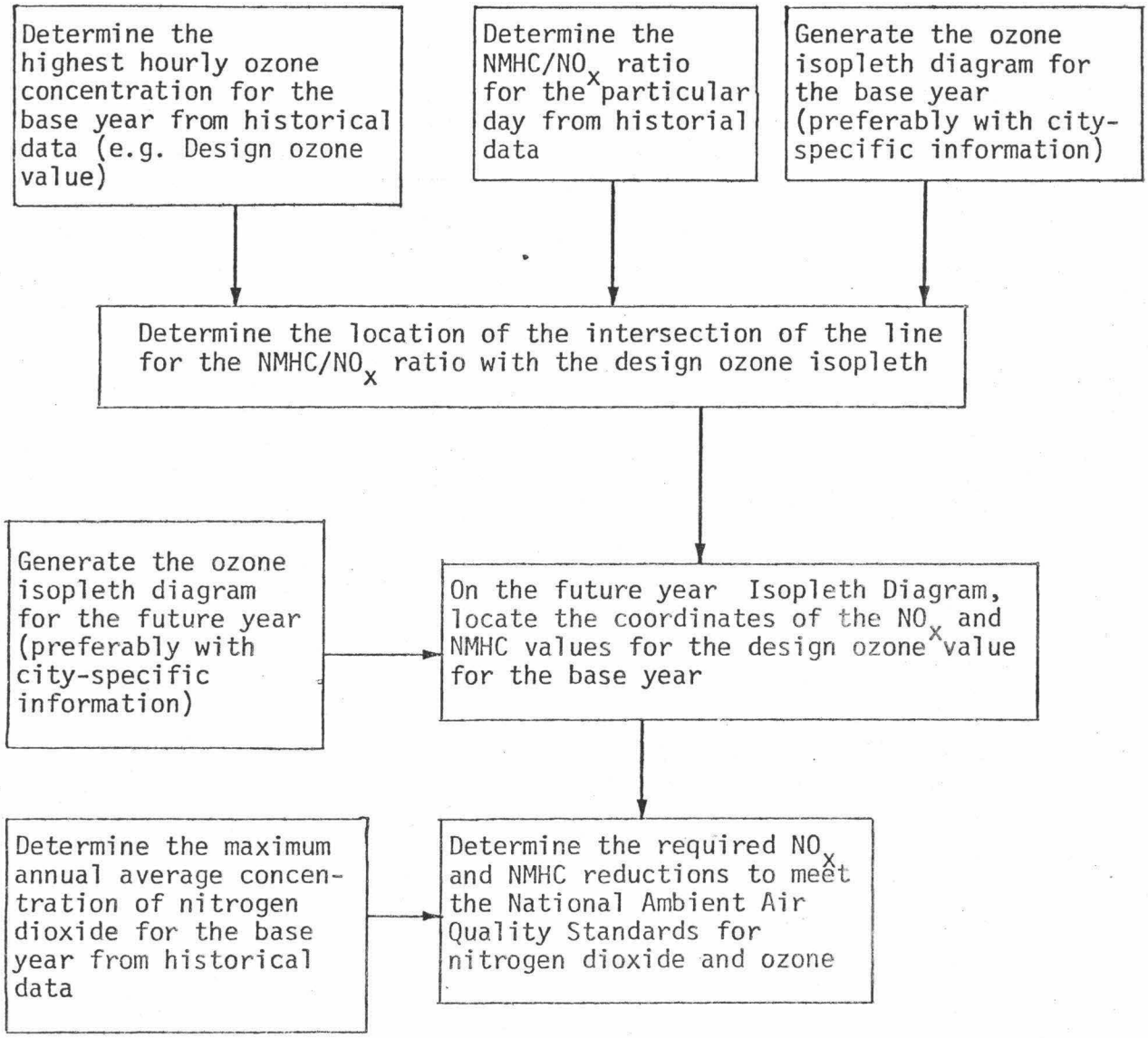



Figure 6. Schematic of steps involved in the use of EKMA to estimate reductions in precursor emissions necessary to meet ambient air quality standards in some future year

The first step in using EKMA is to determine the appropriate NMHC/$NO_x$ ratio and maximum ozone concentration for a given location. The NMHC/$NO_x$ ratio is obtained either from air monitoring data or a suitable emissions inventory. The maximum ozone concentration (also referred to as the ozone design value) is found from actual ambient air quality measurements. The starting point occurs where the line representing the NMHC/$NO_x$ ratio crosses the ozone isopleth corresponding to the maximum hourly average ozone concentration observed. The percentage reductions in NMHC and/or $NO_x$ are calculated from this point. The ambient precursor concentrations above background levels are assumed to be linearly proportional to the corresponding precursor emissions.

EKMA can also be used to determine the reduction in peak ozone concentrations corresponding to a given reduction in precursor emissions. To illustrate this application, consider the following hypothetical example: City "X" is considering an air pollution control strategy in which NMHC and $NO_x$ emissions will be reduced by 40 percent and 30 percent respectively, by 1982. The baseline year precursor emissions should be reduced by the expected fractional emission reductions to determine the future year NMHC and $NO_x$ concentrations. For City "X" the future year NMHC and $NO_x$ concentrations are 0.897 ppmC and 0.265 ppm, respectively:

$$[\text{NMHC}] = (1.0 - 0.4) \times 1.495 = 0.897 \text{ ppmC}$$

$$[NO_x] = (1.0 - 0.3) \times 0.378 = 0.265 \text{ ppm.}$$

The future year NMHC and $NO_x$ concentrations are located on the isopleth diagram to determine the post-control ozone concentration. If the 1982 maximum ozone concentration for City "X" is about 0.35 ppm, then, NMHC and $NO_x$ emission reductions of 40 percent and 30 percent respectively, would result in approximately a 31.4 percent reduction of ozone from the maximum of 0.51 ppm.

$$\frac{0.51 - 0.35}{0.51} \times 100\% = 31.4\% \text{ reduction in } O_3$$

While EKMA is useful as a guide to estimate control levels for hydrocarbons and nitrogen oxides, it is limited in the following respects:

- The mechanism was developed to fit smog chamber data of irradiated auto exhaust and nitrogen oxide mixtures. This mechanism may not adequately simulate actual atmospheres in which automobiles are only a small fraction of the total emission sources.
- The predicted emissions reductions are critically dependent on the initial NMHC/$NO_x$ ratio used in the calculations.
- The isopleth technique ignores the impact of control strategies on downwind areas.
- Emissions are not spatially resolved
- The isopleth approach gives no indication of possible induction effects.

- In most circumstances the isopleth diagrams can not be used in an absolute sense.

GRID-BASED AIR QUALITY MODELS

The second general category of air quality models available for estimating the impact of $NO_x$ emission changes is the so-called class of grid-based models. Grid-based models have received a great deal of attention in the literature and need not be reviewed here. These models are based on solution of the atmospheric diffusion equation,

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} + w\frac{\partial c}{\partial z} = \frac{\partial}{\partial x}\left(K_H\frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_H\frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_V\frac{\partial c}{\partial z}\right) + R$$

on a three-dimensional grid encompassing the region of interest. The advantages of grid-based models are

1. Complete spatial and temporal resolution is possible.
2. Absolute air quality predictions result.
3. The predictions can be compared directly with atmospheric monitoring data.

The disadvantages of grid-based models are two-fold. First, such models require substantial amounts of input data. Secondly, the models are expensive to execute in terms of computing time.

Instead of solving the atmospheric diffusion equation over the entire three-dimensional region, a grid-based model can be exercised in the trajectory format. The concept of a trajectory model is essentially that embodied in EKMA except that the actual emission inventory for the region is used to prescribe the inputs into the moving cell as a function of time. Therefore the trajectory model option of a three dimensional grid model produces absolute air quality predictions along a specific trajectory. Computational requirements for a trajectory model are obviously much smaller than those for a grid model and the predictions from a trajectory model calculation can be compared with air quality data for those stations that the trajectory passes. Although there are certain shortcomings to a trajectory model in terms of treatment of horizontal diffusion and vertical wind shear, the predictions from such a calculation are valuable in attempting to understand the air quality behavior along air trajectories. The equation governing the concentrations in a trajectory model is

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial z}\left(K_V\frac{\partial c}{\partial z}\right) + R$$

where we note that the basic difference between this equation and that in the EKMA model results from the inclusion of vertical diffusion in the trajectory model. If vertical diffusion is neglected, the equation describing EKMA and the trajectory model become identical. The two models then differ only in the manner in which the source emissions along the trajectory are accounted for.

## ESTIMATION OF THE IMPACT OF A LOW $NO_x$ VEHICLE EMISSION STANDARD IN THE SOUTH COAST AIR BASIN OF CALIFORNIA

The air quality models that have been summarized above will be used to estimate the effect of a low $NO_x$ vehicle emission standard in the South Coast Air Basin of California. In this current report we present only the preliminary material relevant to such a calculation. It is anticipated that the full calculation will be available for the report to Congress.

Figure 7 shows the South Coast Air Basin of California and the boundary of the region in which a source inventory has been complied. The grid shown is a ten kilometer grid. Later grid model calculations were carried out on the five kilometer grid as indicated by the small hash marks along the side of the grid. As a preliminary to the low $NO_x$ vehicle emission evaluation we report here calculations using both EKMA and a three dimensional grid model developed at the California Institute of Technology to determine emission reductions required from 1974 levels to meet the Federal ambient air quality standard of 0.12 ppm maximum hourly average ozone concentration. Figure 8 shows an air trajectory for June 27, 1974 that resulted in a peak ozone value of 0.4 ppm. Figure 8 shows the path of the trajectory and also the concentration versus time data for each station close to the trajectory. Figure 9 shows the calculated ground-level ozone concentration from the trajectory model using the Caltech model versus the concentrations at stations as the trajectory model passes those stations. This type of exercise, which must be carried out for a large number of trajectories and days, is the type used to estimate the accuracy of the model.

The trajectory model can be exercised assuming various levels of hydrocarbon and $NO_x$ control to produce isopleths of peak ozone levels as a function of percent reductions of the two precursors. Figure 10 shows such an isopleth plot. Table 1 then indicates the summary of the control levels for hydrocarbons and $NO_x$ required to meet the 0.12 ppm Federal ambient air quality standard for ozone in the SCAB.

### IMPACT OF 1982 - 0.4 GRAMS PER MILE $NO_x$ STANDARD IN SCAB

The estimated impact of a 1982 0.4 g/mi $NO_x$ standard in the SCAB will be performed for inclusion in the report to Congress. This calculation will include projections of growth, stationary source controls, fuel supplies, and motor vehicle emissions.

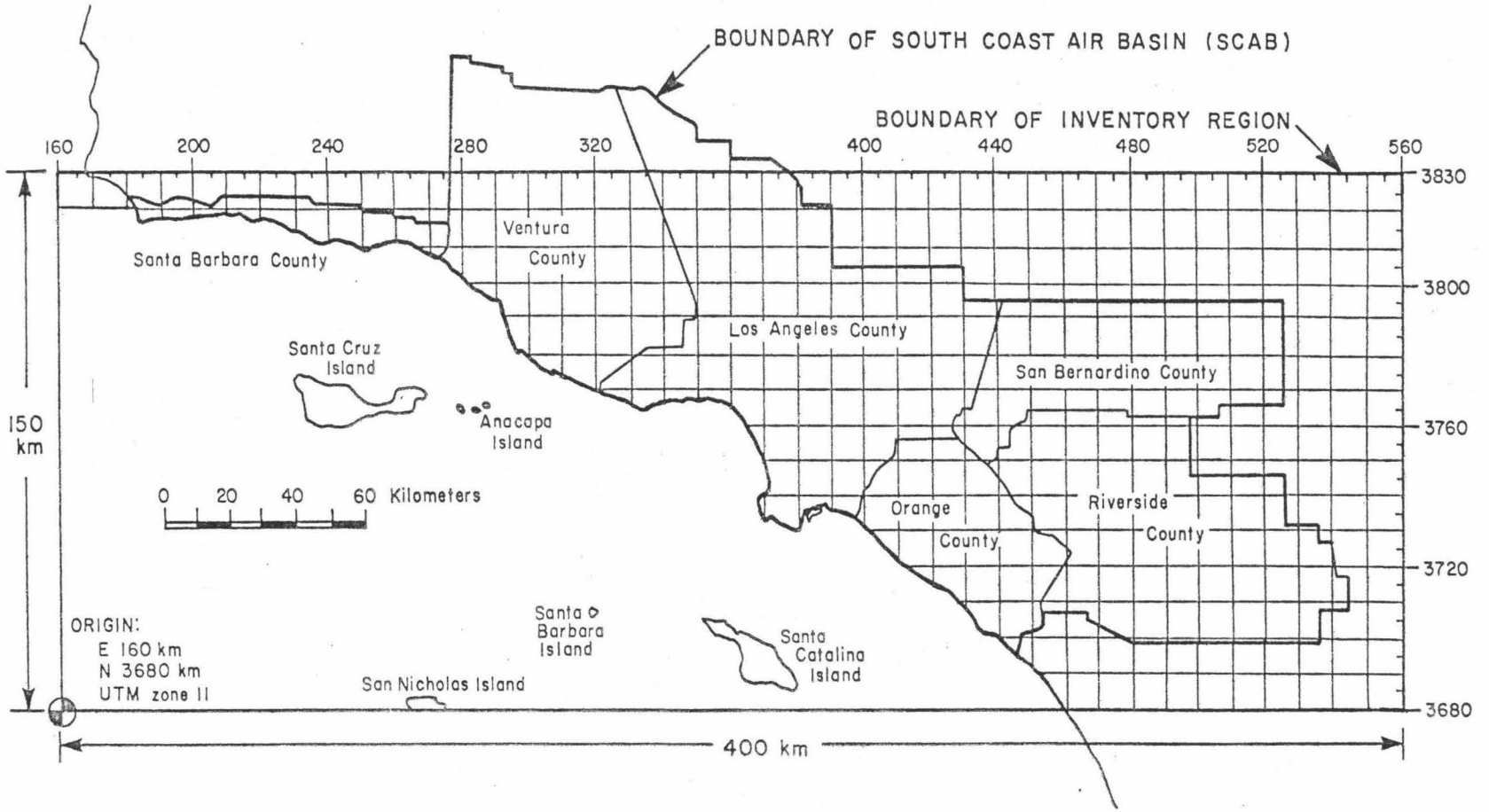



Figure 7. Boundary of the South Coast Air Basin (SCAB) of Southern California together with the grid system used to compile the emissions inventory

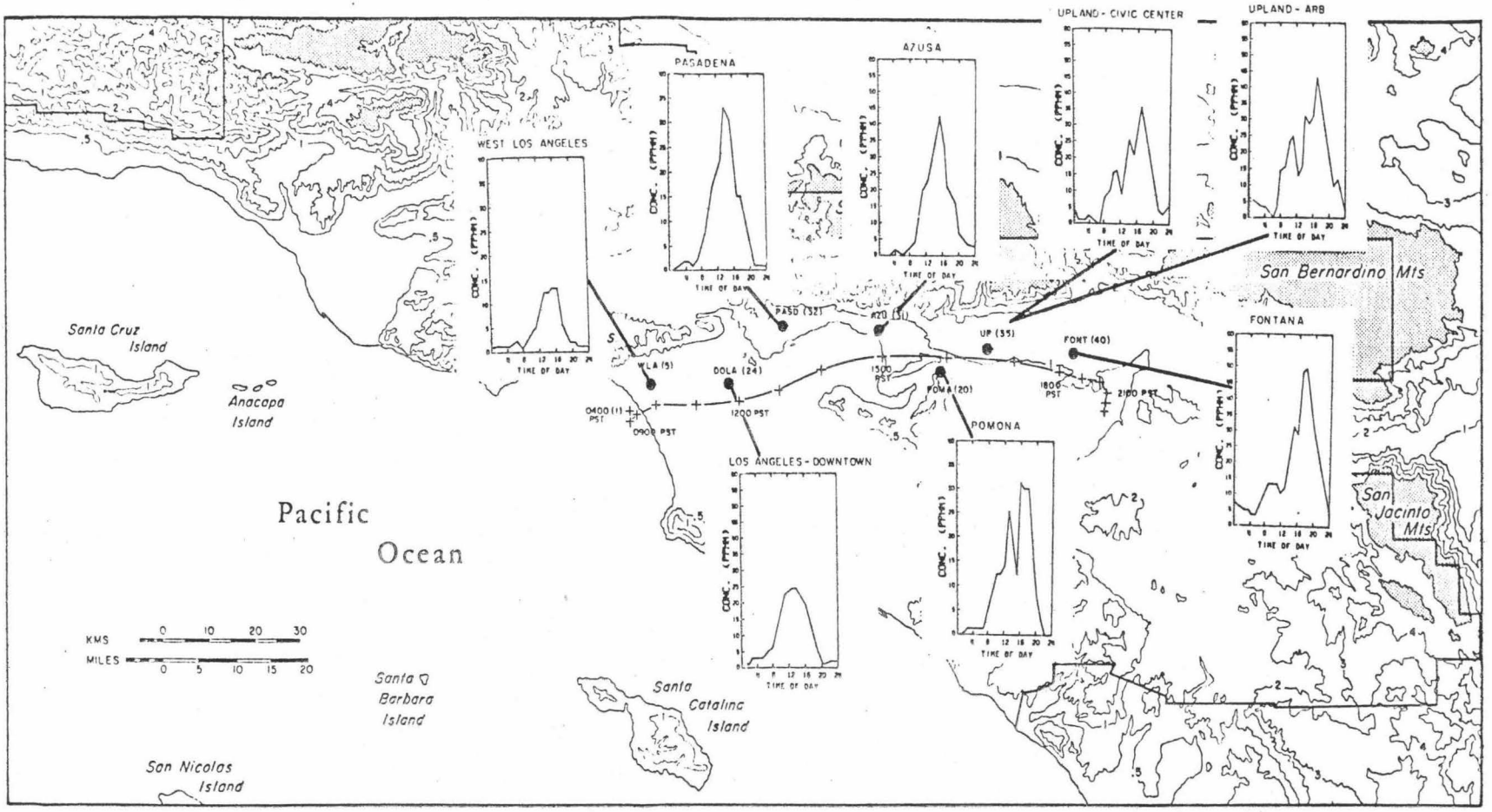



Figure 8. Typical trajectory path for June 27, 1974 and concentration time histories at closest monitoring sites

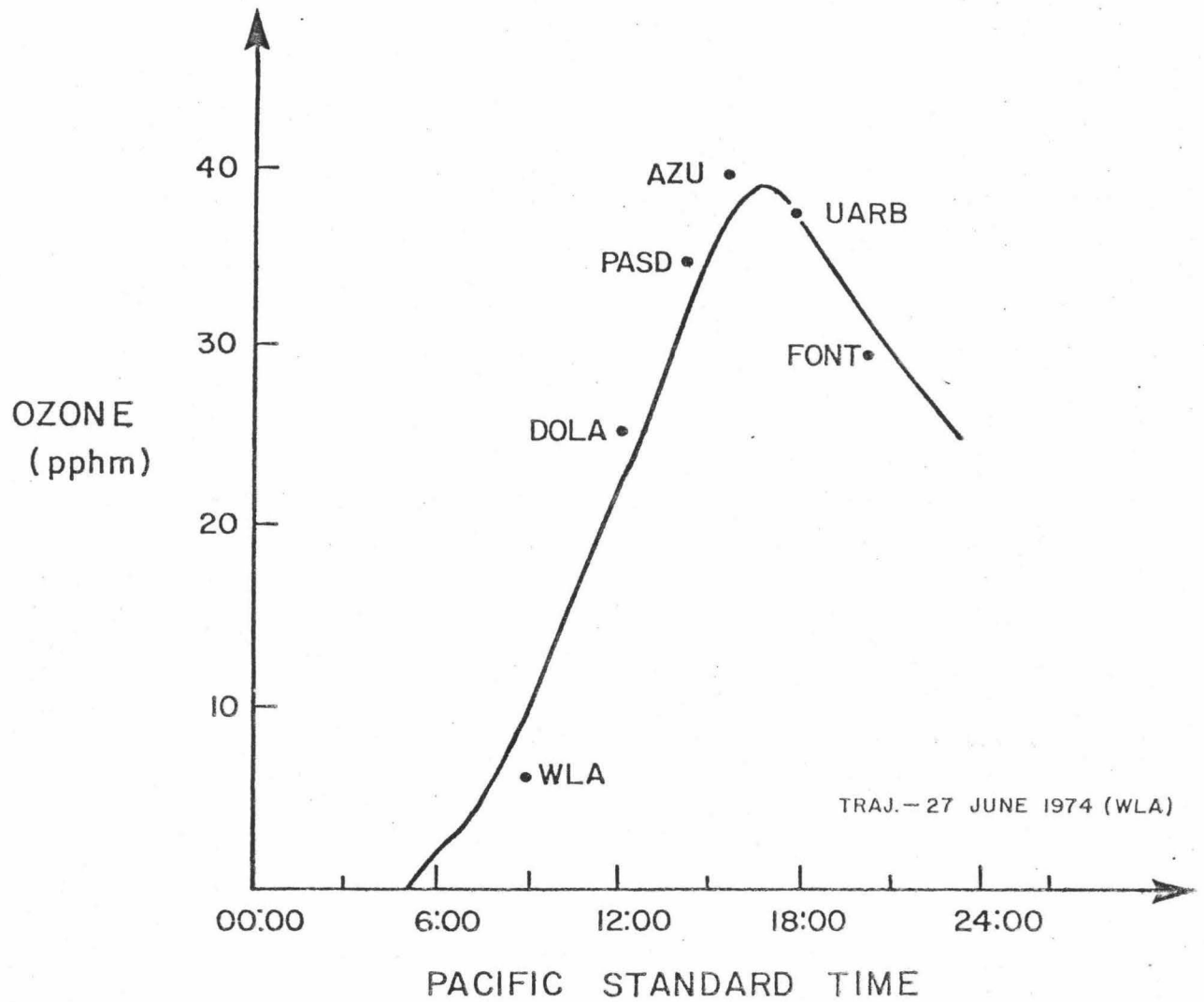



Figure 9. Predicted and observed ground level ozone concentration along trajectory path shown in Figure 8

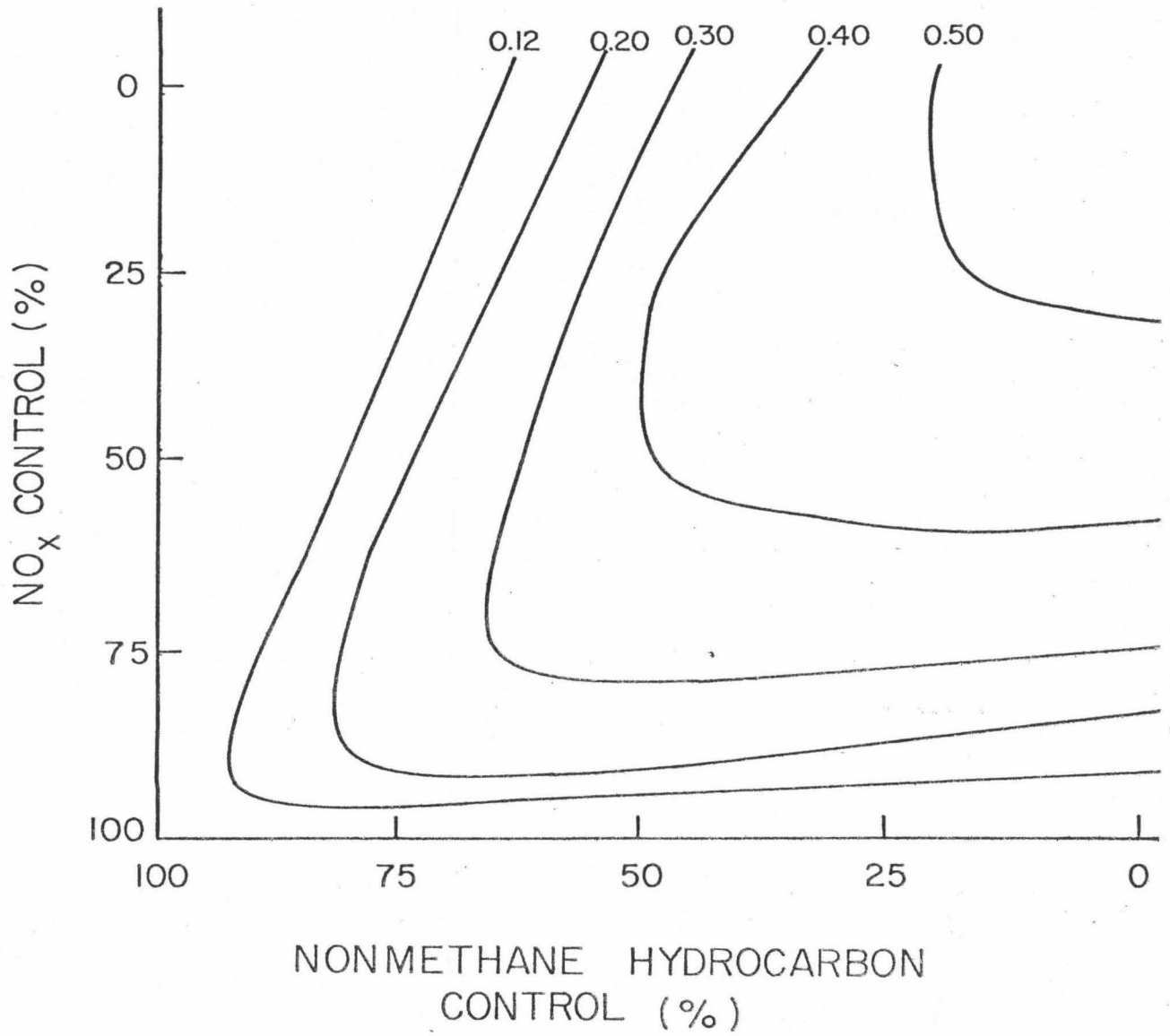



Figure 10. Ozone, isopleth plot corresponding to different levels of control for nonmethane hydrocarbons and nitrogen oxides. (Trajectory path from downtown Los Angeles to Upland 27 June 1974)

TABLE 1. SUMMARY OF CONTROL LEVELS FOR HYDROCARBONS AND $NO_X$ REQUIRED TO MEET 0.12 ppm FEDERAL OZONE STANDARD IN SCAB

| Modeling Method | % Control | |
|---|---|---|
| | RHC | $NO_X^*$ |
| Linear Rollback | 83% | NA |
| EKMA $HC/NO_X = 6.0$ | 80% | 38% |
| Trajectory Model | 77% | 38% |

Design value 0.51 ppmv $O_3$ 27 June 1974

*Based on rollback of Federal annual average standard for $NO_2$

As a preliminary step towards the more refined calculation a series of simpler strategies, involving gross emission changes, have been evaluated using the trajectory and EKMA models. These studies are directed at assessing the impact of different vehicle $NO_X$ standards on oxidant air quality. Four basic cases were considered:

Base Case — The baseline from which to compare different strategies is the 27 June 1974 emission distribution and meteorology of the South Coast Air Basin.

Case A — Assumes a 1.0 gm/mile, light duty automobile, $NO_X$ exhaust emission standard for post-1982 vehicles with no change in any other source categories.

Case B — Same as Case A except that post-1982 vehicles have a 0.4 gram/mile standard.

Case C — Same as Case B except that the $NO_X$ deterioration factor for post-1982 vehicles is set to zero.

Detailed documentation of the base case condition is given in McRae et al. (1979) and will not be repeated here. The future year 1987 was selected to ensure that a sufficient number of post-1982 vehicles would contribute to the $NO_X$ emission distribution. As can be seen from Table 2 approximately 70% of the light duty automobile fleet contribution to vehicle miles travelled (VMT) would come from automobiles introduced after 1982. Table 3 in turn gives the relative contribution of light duty vehicles to the total mobile VMT.

TABLE 2. PERCENT OF TRAVEL BY VEHICLE AGE FOR LIGHT DUTY AUTOMOBILES IN THE SOUTH COAST AIR BASIN

| Vehicle Age (Yr) | % of VMT | Cumulative % of VMT by Increasing Vehicle Age |
|---|---|---|
| 0 | 0.8 | 0.8 |
| 1 | 12.3 | 13.1 |
| 2 | 16.8 | 29.9 |
| 3 | 14.6 | 44.5 |
| 4 | 12.4 | 56.9 |
| 5 | 10.4 | 67.3 |
| 6 | 8.5 | 75.8 |
| 7 | 6.8 | 82.6 |
| 8 | 5.2 | 87.8 |
| 9 | 3.8 | 91.6 |
| 10 | 2.7 | 94.3 |
| 11 | 1.8 | 96.1 |
| 12 | 1.1 | 97.2 |
| 13 | 0.7 | 97.9 |
| 14 | 0.5 | 98.4 |
| 15 | 0.3 | 98.7 |
| 16-25 | 1.1 | 99.8 |

Source: McRae et al. (1979)

TABLE 3. COMPOSITION OF MOTOR VEHICLE FLEET IN THE SOUTH COAST AIR BASIN

| Vehicle Type | % of Regional VMT |
|---|---|
| Light Duty Automobiles (GVW < 6000 lbs) | 80.4 |
| Light Duty Trucks (GVW < 6000 lbs) | 12.1 |
| Medium Duty Trucks (GVW > 6000 lbs) | 1.4 |
| Heavy Duty Trucks - gasoline powered (GVW > 8500 lbs) | 2.5 |
| Heavy Duty Trucks - diesel powered (GVW > 8500 lbs) | 2.5 |
| Motorcycles | 1.1 |

Source: McRae et al. (1979)

In preparing the emissions for each case it was assumed that only the exhaust contribution from light duty vehicles was different from the base conditions. From a practical point of view it is important to note that population growth and the likely future impact of stationary source controls have been ignored. The vehicle emission standards and deterioration rates used in the calculation are shown in Table 4. These equations were developed by EPA from two different sources of information. One was the analysis of the emission data derived from testing low mileage 1975 and 1976 California cars during EPA's fiscal year 1974 and 1975 emission factor program. The second method for deriving the emission factor equations is from the EPA in-use emissions model (EPA, 1978). This approach attempts to project average model year emissions by specifically accounting for the influences of maintenance, tampering and key component failures. For $NO_x$, EPA has relied entirely on the in-use model to describe the expected growth in model year fleet emission rates. Considering the severe effects of deterioration it will be necessary to carefully examine the emission factors in Table 4 before attempting a detailed evaluation of the proposed 1982 $NO_x$ standard.

TABLE 4. LIGHT DUTY AUTOMOBILE VEHICLE EMISSION STANDARDS AND DETERIORATION FACTORS

| Pollutant | Standard (gm/mile) | Deterioration equation* | Mileage to exceed standard |
|---|---|---|---|
| $NO_x$ | 2.0 | 1.5 + 0.16Y | 31,000 |
| | 1.5 | 1.1 + 0.16Y | 25,000 |
| | 1.0 | 0.29 + 0.22Y | 32,000 |
| | 0.4 | 0.12 + 0.22Y | 13,000 |
| HC | 0.9 | 0.29 + 0.23Y | 26,000 |
| | 0.41 | 0.13 + 0.23Y | 12,000 |
| CO | 9.0 | 3.8 + 2.3Y | 23,000 |
| | 7.0 | 3.0 + 2.3Y | 17,000 |
| | 3.4 | 1.4 + 2.0Y | 10,000 |

*Y equals vehicle mileage/10,000.

Source: EPA (1978)

If the equations in Table 4 are used, then it is possible to derive the composite exhaust emission rates as a function of vehicle speed. The emission factor program EMFAC5 (Winston, 1975) was used to calculate the emissions for each case and a summary of the results is shown in Table 5. The mobile component of the emission inventory can then be developed using the speed distributions shown in Table 6 and the fact that the average daily VMT is $167 \times 10^6$ miles. Finally, from a knowledge of the split between mobile and stationary sources, the emission levels of $NO_x$ and RHC can be calculated for each of the cases. The absolute levels and the percentage change from the base case are presented in the first two columns of Table 7.

TABLE 5. COMPOSITE EXHAUST EMISSION RATES IN GRAMS/MILE FOR VEHICLE FLEET IN THE SOUTH COAST AIR BASIN

| Speed (mph) | 1974 | | 1987 | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Base Case | | Case A | | Case B | | Case C | |
| | NMHC (gm/mile) | $NO_x$ (gm/mile) | NMHC (gm/mile) | $NO_x$ (gm/mile) | NMHC (gm/mile) | $NO_x$ (gm/mile) | NMHC (gm/mile) | $NO_x$ (gm/mile) |
| 5 | 20.0 | 4.4 | 5.7 | 2.2 | 5.7 | 2.1 | 5.7 | 1.7 |
| 10 | 11.0 | 4.1 | 3.2 | 1.9 | 3.2 | 1.8 | 3.2 | 1.5 |
| 15 | 7.7 | 4.0 | 2.3 | 1.8 | 2.3 | 1.7 | 2.3 | 1.4 |
| 20 | 6.2 | 4.1 | 1.8 | 1.9 | 1.8 | 1.8 | 1.8 | 1.4 |
| 25 | 5.2 | 4.2 | 1.5 | 2.0 | 1.5 | 1.9 | 1.5 | 1.5 |
| 30 | 4.5 | 4.4 | 1.3 | 2.1 | 1.3 | 2.0 | 1.3 | 1.6 |
| 35 | 4.0 | 4.5 | 1.1 | 2.2 | 1.1 | 2.1 | 1.1 | 1.6 |
| 40 | 3.6 | 4.6 | 0.9 | 2.3 | 0.9 | 2.1 | 0.9 | 1.7 |
| 45 | 3.4 | 4.7 | 0.9 | 2.4 | 0.9 | 2.3 | 0.9 | 1.8 |
| 50 | 3.3 | 4.9 | 0.8 | 2.6 | 0.8 | 2.4 | 0.8 | 1.9 |
| 55 | 3.2 | 5.2 | 0.8 | 2.8 | 0.8 | 2.7 | 0.8 | 2.1 |
| 60 | 2.8 | 5.8 | 0.7 | 3.3 | 0.7 | 3.1 | 0.7 | 2.5 |

TABLE 6. VMT DISTRIBUTION BY SPEED

| PEAK PERIOD | | OFF-PEAK PERIOD | |
|---|---|---|---|
| Speed (mph) | % of VMT | Speed (mph) | % of VMT |
| 10 | 0.26 | 10 | 0.11 |
| 15 | 2.40 | 15 | 0.11 |
| 20 | 7.20 | 20 | 5.03 |
| 25 | 35.40 | 25 | 9.39 |
| 30 | 8.25 | 30 | 39.74 |
| 35 | 0.15 | 35 | 0.38 |
| 40 | 43.76 | 40 | 1.19 |
| 45 | 0.09 | 45 | 0.97 |
| 50 | 0.77 | 50 | 11.47 |
| 55 | 1.74 | 55 | 31.70 |

Source: McRae et al. (1979)

TABLE 7. SUMMARY OF PRELIMINARY CALCULATIONS OF THE OXIDANT AIR QUALITY IMPACT OF DIFFERENT $NO_x$ VEHICLE EMISSION STANDARDS FOR LIGHT DUTY AUTOMOBILES IN THE SOUTH COAST AIR BASIN*

| Case | Emission Levels (Tons/day) | | Peak Ozone Predictions (ppm) | |
|---|---|---|---|---|
| | $NO_x$ | RHC | EKMA Model ($RHC/NO_x$=6.6) | Trajectory Model |
| Base Case 27 June 1974 | 1530 | 1370 | 0.45 | 0.45 |
| 1.0 gm/mile $NO_x$ after 1982 with standard deterioration factors | 1153(25)** | 680(50)** | 0.29(36)** | 0.30(33)** |
| 0.4 gm/mile $NO_x$ after 1982 with standard deterioration factors | 1137(26) | 680(50) | 0.29(36) | 0.30(33) |
| 0.4 gm/mile $NO_x$ after 1982 with no $NO_x$ deterioration for post 1982 vehicles | 1063(31) | 680(50) | 0.30(33) | 0.31(31) |

*Trajectory path from downtown Los Angeles to Pasadena.

**Percentage change from base case.

Once the emissions have been established then the ozone levels corresponding to each strategy can be calculated. For comparison purposes both EKMA and the trajectory model were used to determine the peak $O_3$ levels along a path from downtown Los Angeles to Pasadena. The results for each case are shown in Table 7 and, in essence, indicate relatively little difference between models and strategies. From a preliminary assessment it would seem that, unless the deterioration rates can be controlled, there is little to be gained from a 0.4 versus a 1.0 gm/mile $NO_x$ standard. This conclusion should be regarded as tentative until such time as a more detailed calculation is performed using the latest emission factor information.

## CONCLUSIONS

This paper presented an assessment of air quality models and their suitability for evaluating the impact of motor vehicle emission standards. A preliminary calculation, for the year 1987, indicates that unless the deterioration rates for vehicle exhaust control equipment can be reduced there is little to be gained from the adoption of a 0.4 rather than a 1.0 gram/mile $NO_x$ emission standard. Considering the implications of this finding a more refined evaluation will be performed for inclusion in the final report to Congress. The additional material will include an evaluation of the deterioration equations, projections of growth in the South Coast Air Basin study region and the influence of proposed stationary source controls.

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